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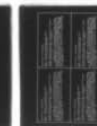
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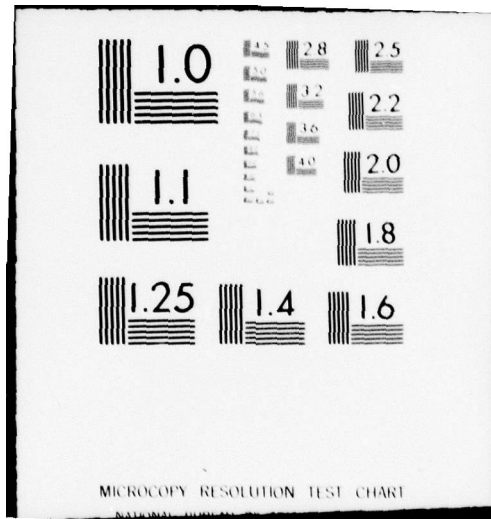
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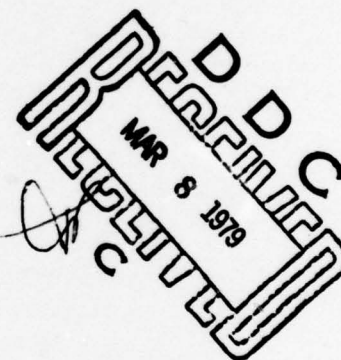
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AN INFRARED THERMAL IMAGING SYSTEM WITH
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B. Montminy
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RESUME

Ce rapport décrit un système d'imagerie thermique comprenant une caméra infrarouge, un convertisseur de balayage digital, un appareil moniteur de type X-Y et un enregistreur magnétique digital. Le système peut servir à enregistrer et à étudier des images infrarouges dans les bandes spectrales de 3 à 5 et 8 à 14 μm . Il peut également servir de système d'interface permettant ainsi le traitement des images sur l'ordinateur. (NC)

ABSTRACT

This report describes a thermal imaging system consisting of an IR camera, a digital scan converter, an X-Y display monitor and a digital tape recorder. The system can be used for recording and studying IR images in the 3- to 5- μm and 8- to 14- μm wavelength bands. It can also be used as an interface system for computer processing of images. (U)

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1.0 INTRODUCTION

This report gives a general description of the Bofors thermal imaging system. It comprises, as shown in Figure 1, a Bofors IR camera, a scan converter with an X-Y display monitor and a digital tape recorder which allows the transfer of IR images from the Bofors camera to the DREV computer. A Tektronix camera included in the system allows one to take photographs from the display monitor and compare, for example, a processed image with its original version.

The main component of the Bofors system is a scan converter designed and constructed at DREV in 1972 and later modified. All pertinent documents concerning the scan converter are listed in the references. They give in detail the building, modifications and evaluation of the scan converter. The work was performed at DREV between April 1974 and April 1975 under PCN 33A10 Improvement to Equipment.

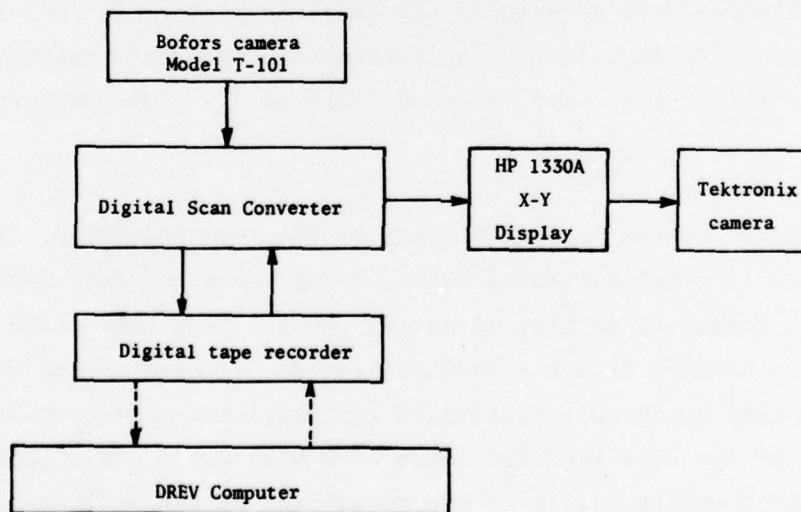


FIGURE 1 - The Bofors thermal imaging system

2.0 THE BOFORS INFRARED CAMERA

The Bofors IR camera is a mechanical scanning device which forms a noninterlaced raster with a frame repetition-rate of 4 frames/s and a vertical resolution of 112.5 lines per frame. The field of view of the camera is 25° horizontal and 12.5° vertical. It can be focussed from 0.25 m to infinity. The detector angular subtense (DAS) is 1.2 mr x 1.2 mr.

The original version of the camera was equipped with a photovoltaic InSb-cell detector using liquid-nitrogen direct-cooling and operating within the 1- to 5.5- μ m band. Later, it was modified at DREV by adding a HgCdTe detector sensitive to IR radiation within the 8- to 14- μ m band.

3.0 THE SCAN CONVERTER

The scan converter is the heart of the system. It transforms the four-frame-per-second image of the Bofors camera into a noninterlaced 30-frame-per-second flicker-free image. It can also be used as an interface system for interactive computer-processing by storing a complete digitized infrared image in its semi-conductor memory.

Figure 2 shows a block diagram of the scan converter. The video signal is first amplified before being converted into digital form by the analog-to-digital converter (ADC). Each conversion takes place upon a command from the synchronization circuits of the camera. Each horizontal synchronization-pulse initiates the analog-to-digital conversion of one line into 256 words of 6 bits while a vertical synchronization-pulse initiates the conversion of the 96 lines forming the image. The choice of a quantization rate of 256 elements per line and 96 lines per image is a compromise between horizontal spatial-resolution and memory size. Each line goes through a buffer

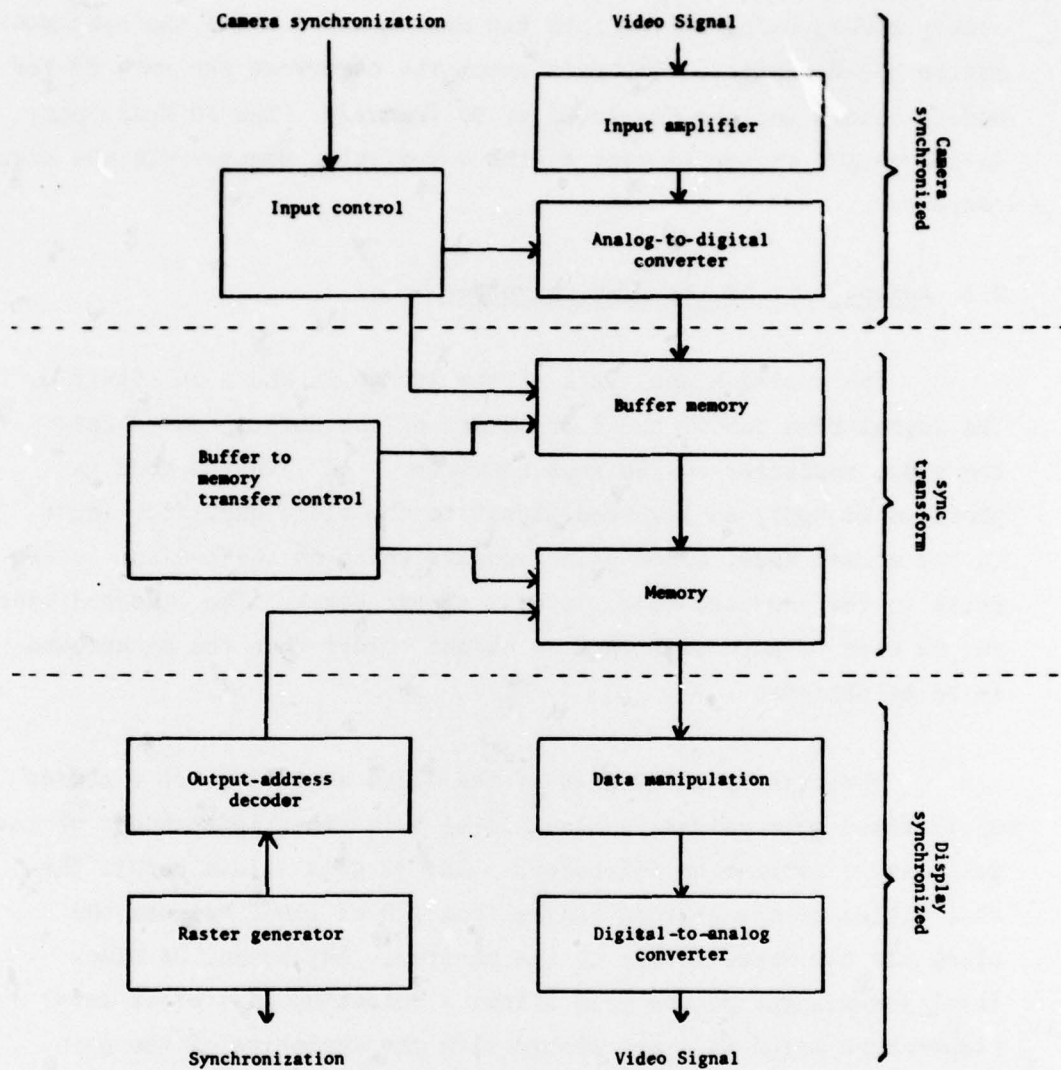


FIGURE 2 - Block diagram of the scan converter

memory before being stored into the main memory, where the synchronization speed changes. The data enter the memory at the rate of the Bofors camera and are displayed at 30 frames/s. The 30 frame-per-second output raster is sent to the X-Y display monitor via the scan converter.

3.1 Analog Part of the Scan Converter

The analog-signal path of the system is shown in Figure 3. The signal from one of the 2 detectors of the Bofors camera feeds the video amplifier of the scan converter. An inverted mode is provided to apply an inverted signal to the video-amplifier input. In the normal mode, a hot point appears white on the monitor screen while in the inverted mode, it will appear black. The inverted mode may be used to advantage when an object colder than the background is to be observed.

The principal features of the video amplifier are a choice of 12 fixed gain values, a black-level adjustment independent of the gain, and 2 saturation indicators. The 12 gain values permit the observation of temperature ranges from 1°C to 150°C between the black and the white levels on the monitor. Adjustment of black level independent of the gain allows a selection of a black-level temperature which will not change with the variation of the gain. The 2 saturation indicators indicate a saturation of the video signal in the black or white level. They help the operator to select the gain and to make a black-level adjustment when desired to view a scene without losing information due to saturation of the video signal. After amplification, the video signal passes through a sample-and-hold module before being converted into a 6-bit digital word by the analog-to-digital converter. The digital word is then put into a buffer.

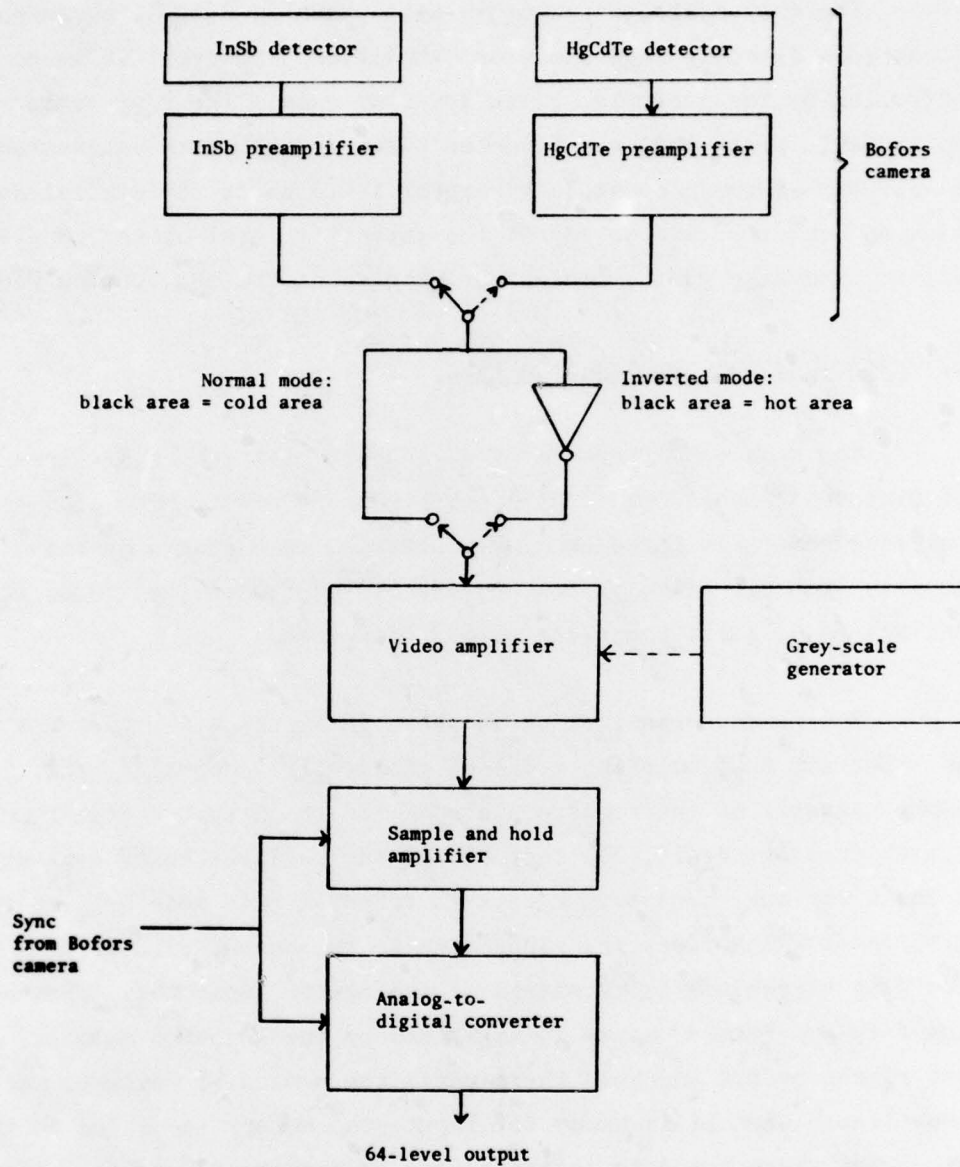


FIGURE 3 - Video-signal path

The grey-scale generator is also shown in Fig. 3, because its output goes directly into the video amplifier. However, it is not controlled by the amplifier black level or gain. The grey-scale amplitude is fixed and goes from the black to the white saturation. The purpose of the grey-scale generator is to check the digital part of the scan converter and to adjust the intensity level of the display monitor according to the ambient brightness of the observation room.

3.2 Memory Organization and Working

The scan converter stores an image consisting of 96 lines of 256 picture elements with 6 bits per picture element. The scan-converter memory is correspondingly arranged in 6 stacks or bit-planes. Each bit-plane represents one bit of the entire image, and consists of 48 shift registers of 512 bits each.

The memory organization is shown in Figure 4. Figure 5 shows the write and recirculating modes of the memory. Normally, the memory operates in the recirculate mode, in which each register recirculates on itself, the last bit of the register being connected to the first one. The output data is taken in this mode by a 48-to-1 multiplexer which feeds the right line to the output circuitry according to the address counters of the raster generator. When a line from the Bofors camera is digitized by the ADC, the data is sent to the buffer and held there until the memory is ready to receive a new line. When it is ready for input, the memory is placed in the write mode where the data in the buffer is transferred to the shift register #1 while the data of each of the remaining registers is advanced to the next register. After the transfer, the memory returns to the recirculate mode. The net effect is that new imagery enters the memory at the top and is scrolled downwards.

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Memory capacity: 24576 6-bit words

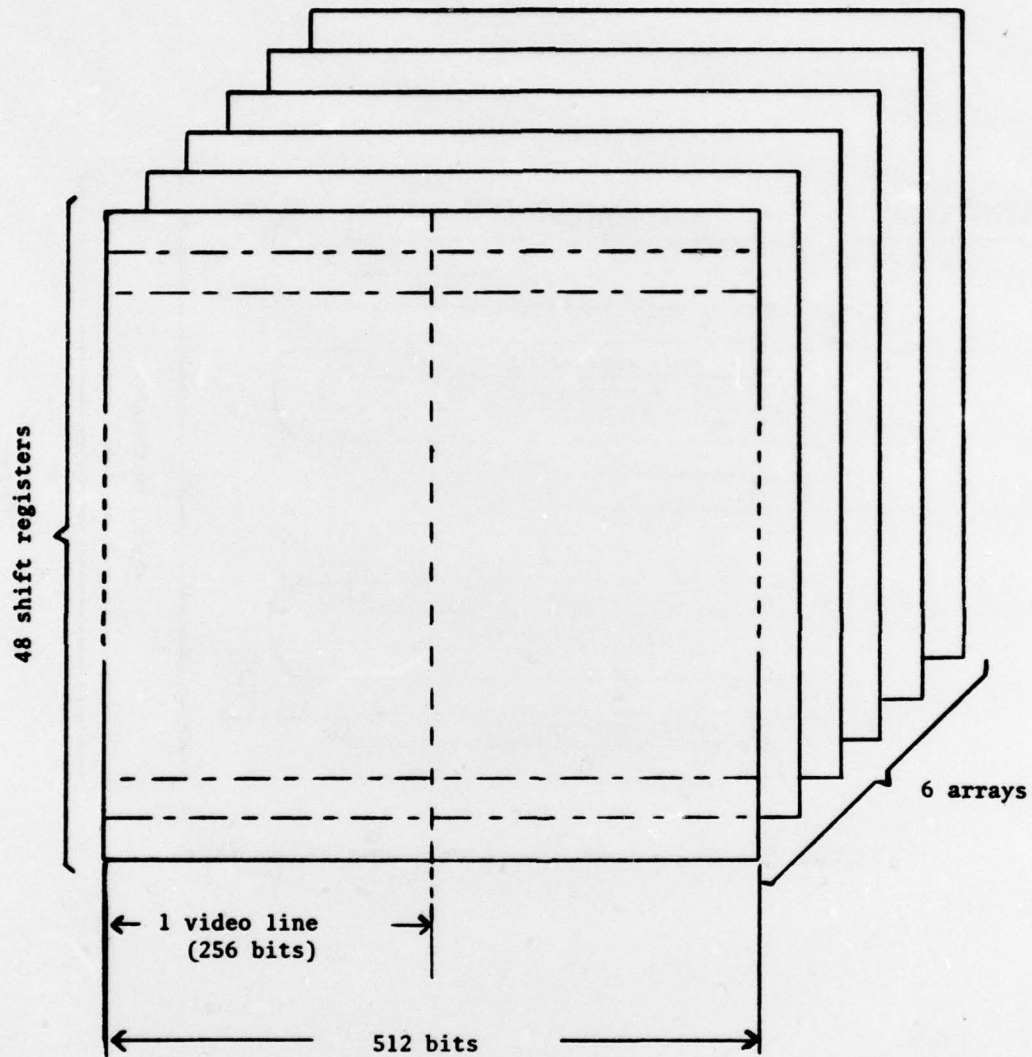


FIGURE 4 - Scan-converter-memory organization

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Two modes: write (———)

recirculate (-----)

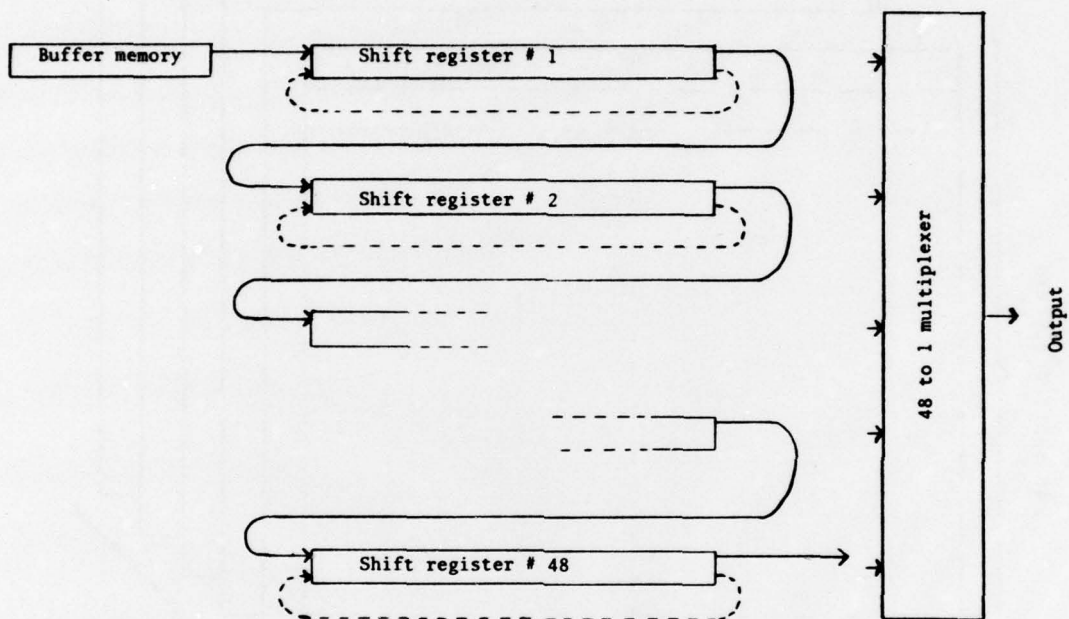


FIGURE 5 - Scan-converter-memory operation modes

3.3 Data Manipulation

Data manipulation permits the generation of 2 functions, the isotherm and the thermal band. Figure 6 illustrates the isotherm function in which some memory levels can be saturated or blackened by means of level and width controls. In this figure, the level is set to 28 and the width to 20 such that the band between levels 28 and 48 ($28 + 20$) is saturated or blackened while the rest of the memory levels are displayed normally. Figure 7 illustrates the thermal-band function in which the gain of the output signal of the scan converter is raised such that only a part of the 64 memory-levels is displayed between the minimum and the maximum brightness of the display monitor. It shows a setting of 28 for the level, and 20 for the width such that level 28 is the minimum brightness level on the monitor and level 48 ($28 + 20$), the maximum. The rest of the picture can be saturated or blackened.

4.0 THE DIGITAL TAPE RECORDER

The digital tape recorder of the system is an all-purpose digital-instrumentation recorder, (Model ADIR-1093 Astro-Science Corporation). This recorder can read and write synchronously at a speed of 37.5 in/s into an IBM System 360 format using 9 tracks of 800 bits per inch. It is the link between the scan converter and the DREV computer, because a complete frame can be transferred from the scan-converter memory to a digital tape and then read by the computer. Each recorded frame contains 24576 words of 7 bits recorded on 7 tracks on the digital tape. The 7 bits recorded are composed of data bits plus a parity bit added by the tape recorder. Two spare tracks are left on the tape. The tape format, shown in Figure 8, represents the first frame on a digital tape. After the beginning of the tape (BOT), an initial gap is left before the recording of one frame.

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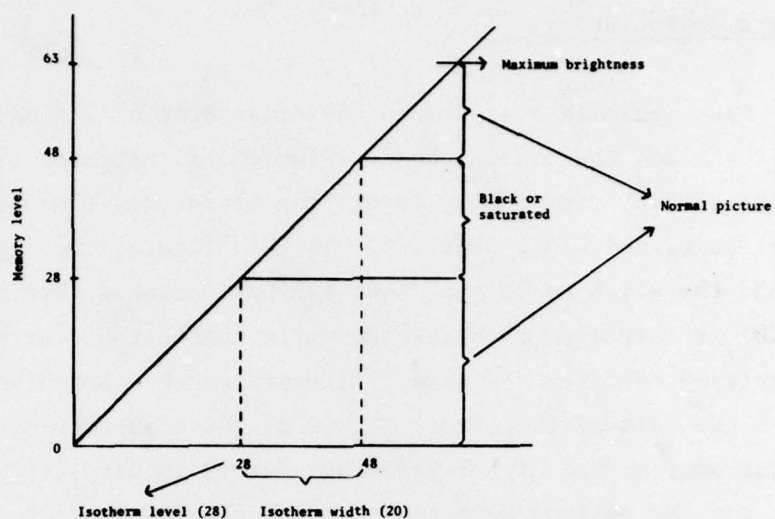


FIGURE 6 - Isotherm function

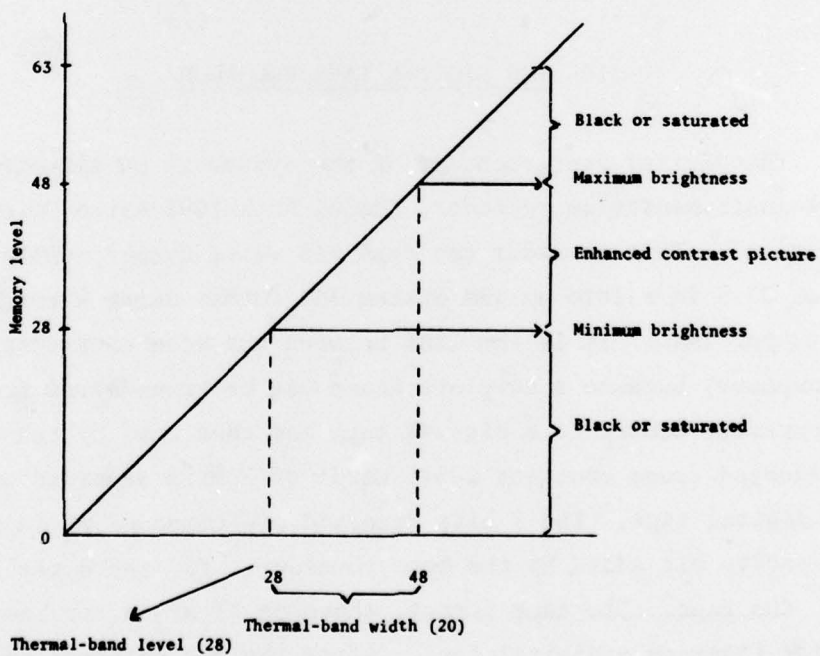


FIGURE 7 - Thermal-band function

After each frame, a cyclic redundancy check character (CRCC) and a longitudinal redundancy check character (LRCC) are recorded on the tape. These recording steps are necessary for IBM compatibility.

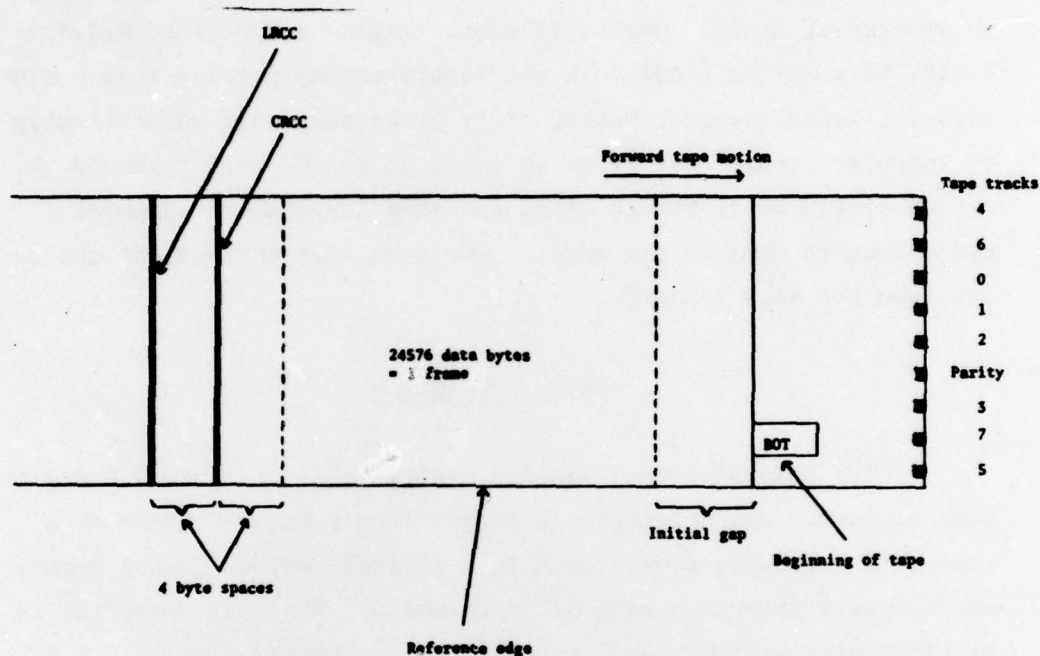


FIGURE 8 - Digital-tape format

5.0 FEATURES OF THE BOFORS SYSTEM

The main features of the Bofors system are the speed at which pictures can be recorded, the precision that can be achieved when studying the temperature distribution of an image because of the digital form of the scan converter and its use as an interface system for computer digital-processing of images.

As an example of the importance of speed in forming images, consider the problem of collecting ship IR signatures in which many IR images of the ship under different angles and with different amplifier gains must be recorded. With the Bofors system, at least

one image may be recorded every minute, with different black-level and gain settings for each. With the 2 detectors of the Bofors camera, ship infrared-signatures can be studied in the 3-to 5- μm and 8-to 14- μm wavelength bands. Once sufficient images have been recorded in the field, they may be studied in the laboratory by putting them again into the scan-converter memory or by processing them automatically by computer. Figure 9a is an IR image of an APC M113 taken by the Bofors system while Figure 9b is the same image after computer processing to enhance the edges. The same edge enhancement can be obtained for ship imagery.

6.0 CONCLUSION

The Bofors thermal imaging system is formed around a digital scan converter which accepts IR images from a Bofors camera at a rate of 4 frames/s, stores them in a digital semi-conductor memory and displays them at a rate of 30 frames/s. The scan converter is provided with isotherm-and thermal-band functions as well as gain and black-level adjustments for the video signal. A digital-tape recorder is also part of the system permitting the recording of Bofors camera IR images in digital form for computer processing. Thus, for example, this system allows one to record rapidly many images of a ship so as to permit later study of its IR signature with the scan converter facilities or by computer processing.

7.0 ACKNOWLEDGEMENTS

The authors wish to thank specially M. Lessard for his work on this thermal imaging system. The authors also thank G. Morley and Dr. W.G. Tam for their many helpful comments on the preparation of this document, and L. Sévigny for supplying the photos for Figures 9a and 9b.

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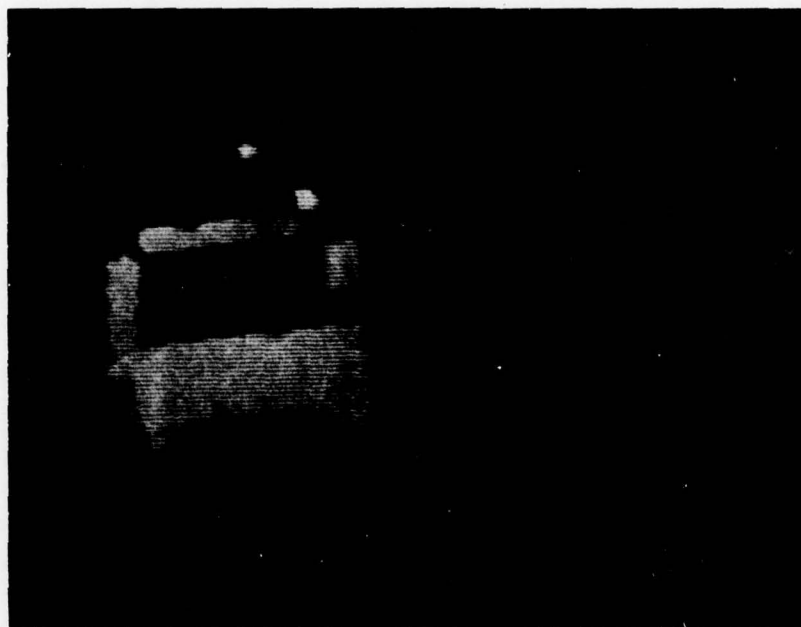


FIGURE 9a - An IR image of an APC M113 taken with the Bofors system

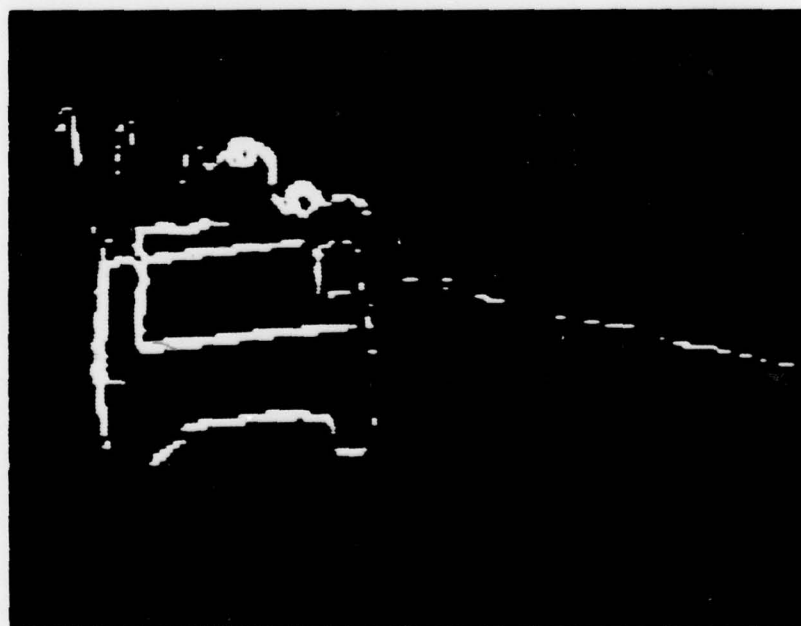


FIGURE 9b - The same image of the APC M113 after computer processing

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